

GRAPHICAL COMPUTER METHODS IN THE DESIGN OF INTEGRATED CIRCUITS

By

V. SZÉKELY, P. BAJI and M. RENCZ

Department of Electronic Devices, Technical University, Budapest

Received October 5, 1979

Presented by Prof. Dr. K. TARNAY

The state-of-art of the Computer Aided Design in Hungary

Nowadays, the increased computer efficiency and the results in the field of algorithms could make of the computer a very important help of the designer. In spite of it, in Hungary the computer methods are not much employed in engineering practice. Other fields thought to develop slower than engineering (e.g. administration), are on a higher level in using computerized methods, and they use computers to a great part of their work. The likely cause of it is the organization of the communication between the computer and the user. A great part of the administrative tasks can be performed by batch processing, and with conventional peripheral equipment, typical of the first decade of computer technique. On the other hand, the engineering design usually requires interactive communication between the computer and the user and often requires special peripherals (e.g. for the visualization of graphical information). The means for this cannot be regarded general even today. Besides, while the solution of the mathematical problems of data processing usually do not require more than the four rules of arithmetic, the solution of many algorithmical problems of engineering have proved to be a research field for decades.

The role of the education

This problem, general in engineering practice cannot be said to be bypassed in the educational practice at the Technical University. The curriculum included teaching of the bases of ALGOL or FORTRAN programming languages, and the teaching of surveying knowledge about the numerical methods, before a decade. The lecturers of the Chair of Electron Devices had also invested a lot of work to integrate these topics in regular education. They are not considered as useless even today in the respect that they contribute to the general professional culture of our students.

Nevertheless it is recognized again and again that these knowledges in the computer technique cannot be used directly in practical engineering, and when an engineer uses computer technique today—by accident—he does not do it as he was taught in the corresponding course. How can computer technique be used in engineering design effectively and economically? Today we can already see: not so that the engineer prepares in each case “his own little programme” for his actual problem. A feasible arrangement is to make general purpose programmes for the really often arising problems. Not only the algorithm, precision and running time of these programmes have to be optimized, but the man-machine contact, the ergonomical design are similarly points of interest. Their usage generally does not require special knowledge (e.g. programming), only a basic intelligence in computer technique.

This tendency raises new demands on the education of engineers. We have to teach our students (over the general knowledge about computer technique) how to use the engineering design (CAD) programmes. The choice between existing programmes has to be demonstrated and these (or at least a part of them) have to be available, and our students must be accustomed to use them. According to the nature of the problem, it is a task of the engineering departments.

The CAD and the graphical-interactive methods

The trend in the progress of the CAD raises accurate demands for the designers who develop the programmes. They have to concentrate their powers not only to the algorithms of the new programmes, but to design the features of use with meticulous care, developing a form fitting the given problem, and attractive for the user.

Within the scope of the research work on CAD, the questions of the interactive and graphical organization of the design programmes have been dealt with for a long time at the Chair of Electron Devices. These methods have a particularly great importance in the design of integrated circuits.

On the one hand, because the planning of the IC masks means in most cases operations on geometrical formations and the results of the other steps of the design can also be well-demonstrated graphically, on the other hand, because many steps of the design process demand interactivity.

Our Department has elaborated the software of a graphical interactive system for IC design for the REMIX Electronic Components Factory within the framework of a longtime collaboration.

Three programmes of this system are interesting with respect to our topics:

— TRANZ-TRAN 3/D, a nonlinear circuit analysis programme [1] with graphical display input and output and with interactive provisions needed for the IC design,

— THIN-IC/THICK-IC, a display-interactive programme for mask design and mask realization of thin film and thick film integrated circuits [2].

— THERMANAL, a graphical-interactive programme for calculating the heat distribution of the IC chips.

All these programmes can be run on the TPA-i computer, using a 180×240 point raster display for graphical communication. The GAS (graphical basic software) and GS (graphic software) programme packages, which supply the graphical functions of the system have been developed also by our chair.

Defining the functions of these two subroutine packages, the problem of the graphical-interactive design was primarily considered.

Practical questions of the graphical-interactive design programmes

The limited picture screen magnitude and resolution

The figure to be displayed is too big for the screen: scaled down it will lose significant details. This problem emerges even in a vector-display with good resolution and it is faced practically in all cases of using a 180×240 point raster display. As solution of the problem we have used a method widely spread in display technique. Rather than the whole picture, only a part of it is seen on the screen, so to say through a window. The designer can shift the picture behind this "window", he can scale it up or down, so after all he can inspect any part and detail of it. Most of the window functions are provided by the basic software GAS-GS. It allows drawing on a 2048×2048 points virtual picture field—and with a single instruction the part of the virtual picture to be displayed can be assigned. Developing the window functions we considered

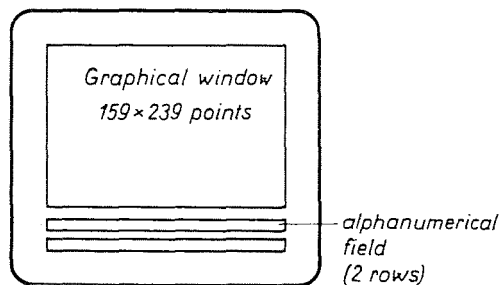


Fig. 1. The display screen with the graphical window, with the alphanumeric field below

that the pictures of the interactive operation often require captions that must not overlap with the graphical information. This is why the graphical window—displaying a part of the virtual picture—is a little smaller than the whole screen (Fig. 1) and the field remaining under it is reserved for captions (alphanumerical field).

Output on the screen

Writing our output segments was commanded by two aspects:

- to utilize the possibilities of visual-graphical demonstration,
- to find a way of communication not unusual in engineering practice.

Let us see how the output data of the circuit analysis programme are represented. At the end of the d.c. analysis the scheme of the circuit appears on the screen (Fig. 2) and a little framed field is seen in the bottom right corner of the screen. The latter functions as a display of a digital voltmeter: the voltage of a node of the circuit pointed at appears in the frame. For pointing at the screen the input device is the track ball. It is a manipulator which can be turned in

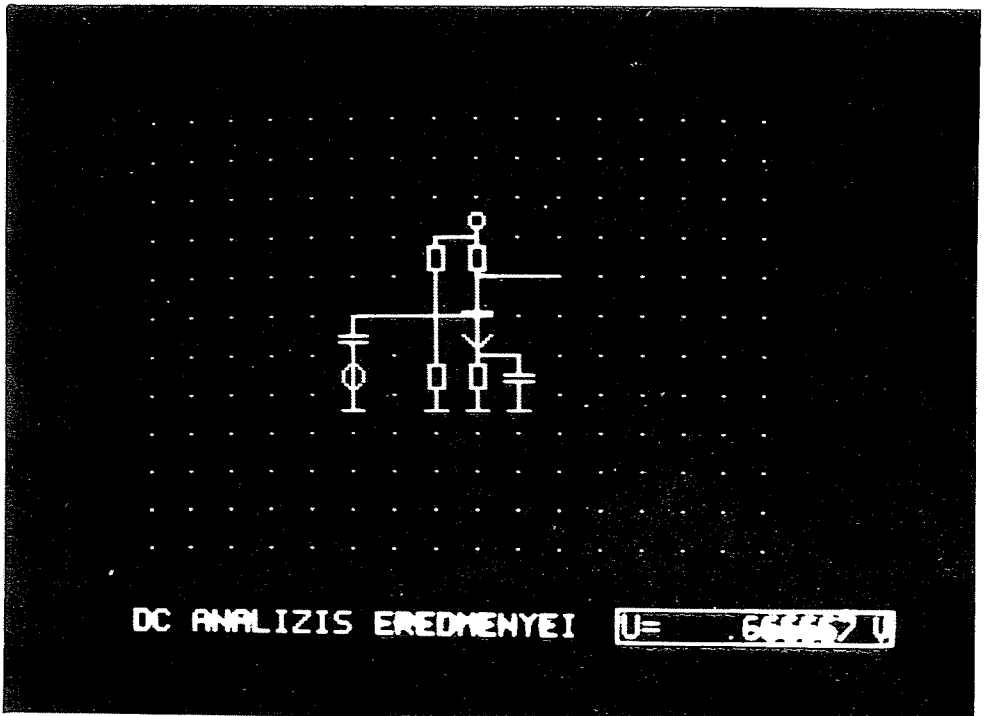


Fig. 2. After a DC analysis by TRANZ-TRAN 3/D the analysed circuit appears on the screen and the voltages of the nodes can be questioned by means of the track ball (EREDMÉNYEI = results)

both vertical and horizontal directions. In accordance with its motion a bright point, the CURSOR is moving on the screen.

The results of a transient analysis are voltage-time functions. These functions appear on the screen (Fig. 3) referring to the node denoted by the CURSOR, as if the wave form were tested by an oscilloscope. The parts of the function may be examined by enlargement as well. More voltage-time functions can be studied at the same time as like as with a multi-channel oscilloscope. It was an additional problem that owing to the low resolution it was out of question to draw scaled coordinate axes for the functions. The CURSOR is used to get numerical data of the functions. While displaying the functions two data are seen in the framed field of the bottom right corner (Fig. 3.)—these are the coordinates of the actual CURSOR position. Thus the data of any point of the function can be read off. The method has proved exact and very comfortable for the user. We think it the most suitable way even if we have a display with high resolution. The THERMANAL program calculating the heat distribution on the IC chips sets up special claims on the result output. Now the information to be displayed is the two-dimensional heat distribution in an IC chip surface. An output form we have chosen is to display the isotherm

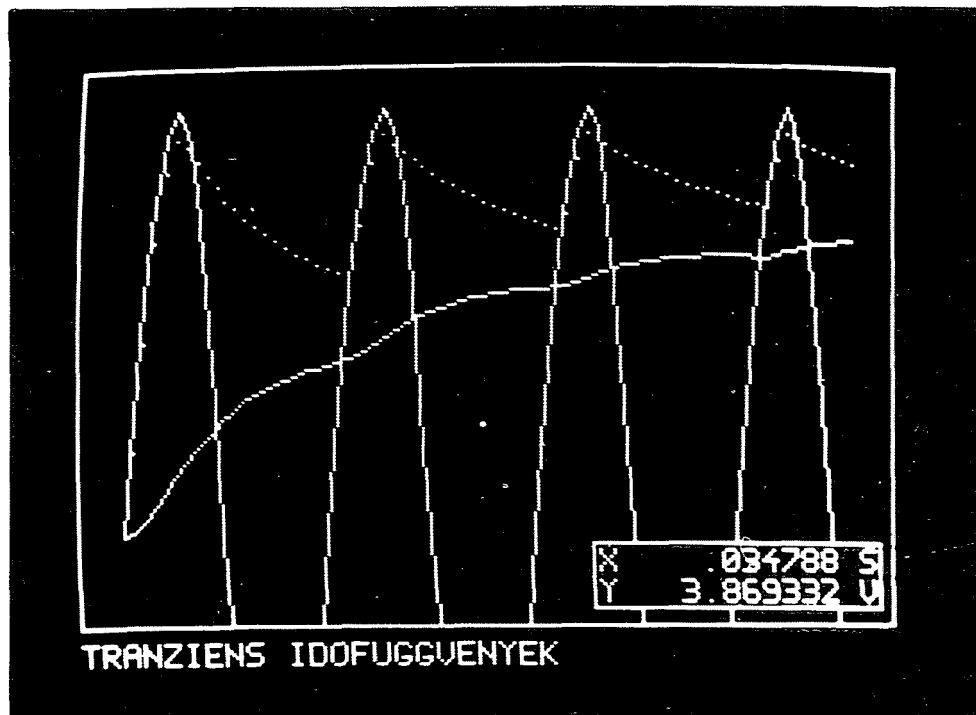


Fig. 3. After a transient analysis by TRANZ-TRAN 3/D the voltage-time functions appear on the screen (IDŐFÜGGVÉNYEK = time functions)

lines. The picture on the screen is similar to a relief map, it is easy to analyse—and it is easy to survey the heat (Fig. 4) distribution of the chip. The results are often parts of a technical documentation too, in this case it is necessary to produce a hard copy. The best solution would be to use a matrix-printer, it could print the raster display picture directly on paper. In lack of this we had to provide the THERMANAL programme with a segment instructing a digital plotter to draw the diagram of the heat distribution.

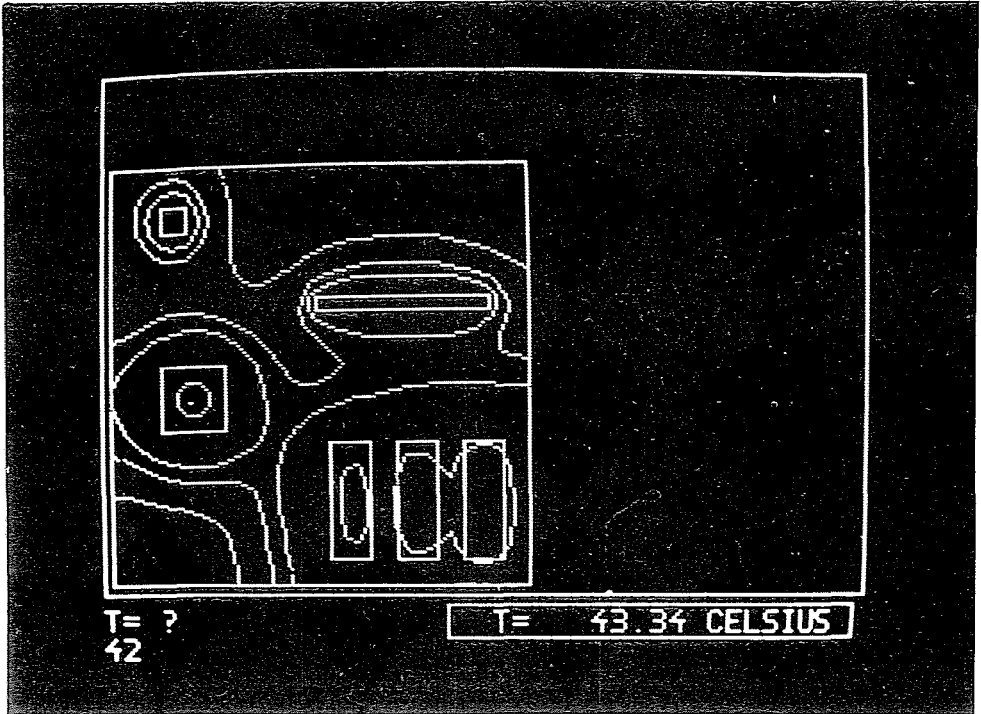


Fig. 4. An output possibility of the THERMANAL programme, the isotherms of the IC chip

Graphical display and interactivity

The display screen helps the design of thin and thick film IC-s as a drawing table with special possibilities. The picture parts appearing on it may be e.g. moved or turned round. All of these are interactive operations. We move the CURSOR onto the element under position, and type on the keyboard, if a turning is needed. This in how to design step by step the layout of the IC (Fig. 5).

The components can be displaced in a similar way. Between these operations the scale of the picture can be changed. Designing IC chips having components in both sides: the IC substrate can be "turned" on the screen to examine its other side.

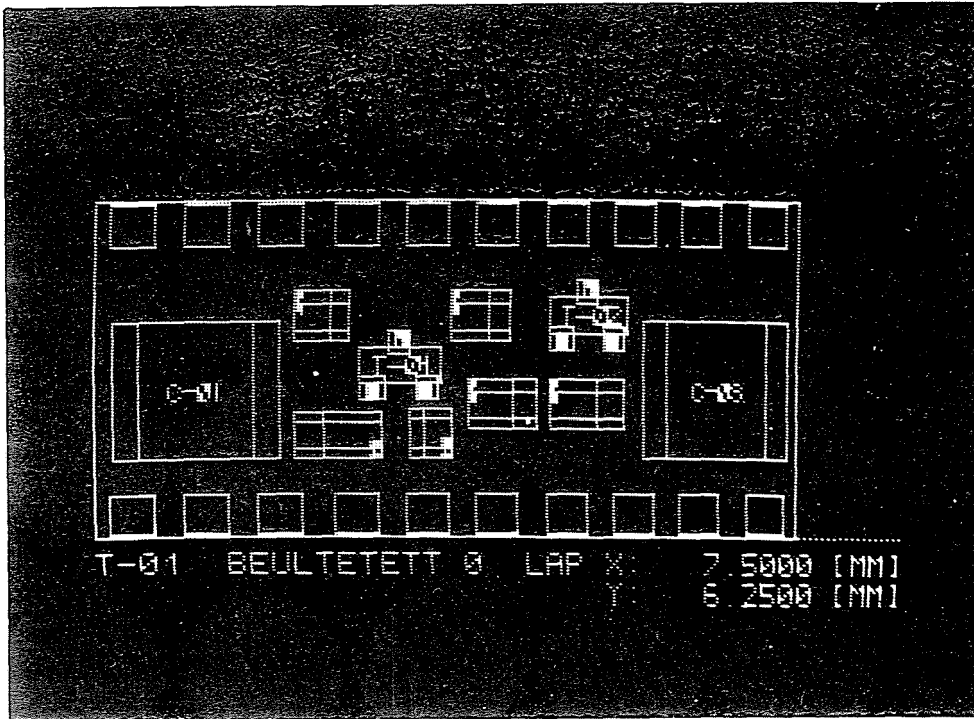


Fig. 5. The final IC layout designed by the THICK-IC programme

The circuit input and modification are interesting graphical interactive provisions of the circuit analysis programmes. The designer draws the circuit to be examined on the display screen. The required place of the element is indicated by the CURSOR. Afterwards the programme asks the type and value of the treated element, etc. This is how the circuit-sketch seen in Fig. 2 was composed. The elements may be deleted or modified, not only at the first input, but before each part-analysis.

Ergonomical problems

When writing interactive programmes it has to be considered that a part of the user's actions may be erroneous. These actions must neither withhold nor slow down the effective use of the programme.

The conditions of this:

- the computer must indicate immediately the user's errors as soon as detected;
- after the indication there must be a simple possibility of correction.

Our usual method is the following: a flashing question mark appears for the step that has been carried out wrongly.

The response-times of the computer

Prompt computer answers have to be striven for in the man-machine dialogue. The machine must not delay more than some seconds. When this is not possible (e.g. in a circuit analysis, where the time of calculation is in the range of minutes) we have to think of the golden rule of writing display-interactive programmes [3]; "It is a potential source of the panic in front of the screen when the user does not know

- whether there is something happening
- how long more it lasts."

Accordingly, when the machine computes longer than a few seconds the screen must not remain dark. Moreover a still picture would not be sufficient, the screen must "live" to reassure the designer's mind that the machine is working. During longer computation times we try to indicate continuously the progress of the computation.

In our opinion in the programmes supporting engineering work, interactivity and visual-graphical communication have to be striven for. The above mentioned are our experiences, problems and results in this topic. The hardware possibilities of interactive computer use the graphical displays are now spreading. We hope this will stimulate the usage of the CAD programmes.

Summary

Within the scope of the research on Computer Aided Design, the questions of the interactive and graphical organization of the design programmes have been dealt with for long at the Chair of Electron Devices of the Technical University, Budapest. The TRANZ-TRAN 3/D, THERMANAL, THICK-IC, THIN-IC graphical interactive design programmes will be presented with the aid of display screen photos.

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Dr. Vladimír SZÉKELY Pál BAJI Dr. Márta RENCZ	}	H-1521 Budapest
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